# Recommended Descriptions of Geosynthetics Functions, Geosynthetics Terminology, Mathematical and Graphical Symbols

## Foreword

This is the fifth edition of the IGS mathematical and graphical symbols document. Since publication of the fourth edition in August 2000 a number of evolutionary changes (rather than revolutionary changes) have been made to reflect the further development and refinement of geosynthetics terminology. This edition will also be placed on the IGS Web Site to provide IGS members with ready access to current geosynthetics descriptions, terminology and mathematical and graphical symbols.

Further updates will follow as the range of products, applications and related terminology expands.

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## 1. Geosynthetics Functions

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| Barrier | The use of a geosynthetic material to prevent the migration of liquids or gases. |
| Containment | The use of a geosynthetic material to contain soil or sediments to a specific geometry and prevent their loss. The contained fill takes the shape of the inflated at-rest geometry of the geosynthetic container. |
| Drainage (also known as transmission) | The use of a geosynthetic material to collect and transport fluids. |
| Filtration | The use of a geosynthetic material to allow passage of fluids from a soil while preventing the uncontrolled passage of soil particles. |
| Protection | The use of a geosynthetic material as a localised stress reduction layer to prevent or reduce damage to a given surface or layer. |
| Reinforcement | The use of the tensile properties of a geosynthetic material to resist stresses or contain deformations in geotechnical structures. |
| Separation | The use of a geosynthetic material between two dissimilar geotechnical materials to prevent intermixing. |
| Surficial erosion control | The use of a geosynthetic material to prevent the surface erosion of soil particles due to surface water run-off and/or wind forces. |
| Frictional interlayer | A layer introduced within an interface with the purpose of increasing or reducing friction across the interface. |

## 2. Geosynthetics Terminology

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| Abnormal test result | A result that lies more than three standard deviations from the mean. |
| Abrasion | The wearing away of any part of a material by the action of friction or rubbing. |
| Abrasion resistance | The ability of a material to resist wear due to friction or rubbing. |
| Absorption | A mechanism by which a fluid is assimilated by or taken up into a material or its constituents or both. |
| Anisotropic | Having directionally variable properties. |
| Antioxidant | A substance designed to retard or prevent oxidative degradation of a material. |
| Apparent opening size | See: *opening size* |
| Barrier | A basic geosynthetic function. A term used by ISO 10318 to describe geosynthetics with main constituents of bituminous, clay and polymeric origin which perform barrier functions. |
| Bituminous geomembrane | See: *geomembrane, bituminous* |
| Bonded geogrid | See: *geogrid bonded* |
| Basecloth | A textile fabric, usually woven, which may be included in a needled felt to provide dimensional stability and strength and in some cases to facilitate the needle-punching operation |
| Batch | A defined quantity of a geosynthetic manufactured, produced, or stored under conditions presumed to be uniform, or a quantity purchased or offered for sale or for sampling at the one time. (See also order and sample.) |
| Batt | Single or multiple sheets of fibre used in non-woven fabric production. |
| Biaxial | Behaviour testing or performance that takes place in two orthogonal directions. |
| Binder | An additive used to bind fibres together. A binder may be of a chemical, adhesive, resinous, or fibrous nature. |
| Binder content | The mass of binder added as a percentage of the total mass of the geotextile. |
| Binder fibre | A fibre that has a relatively low softening point compared with other fibres in the web, and which, on the application of heat or pressure, acts as an adhesive. |

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| Bonding | The process by means of which one or more sheets, webs, or batts of fibre are held together. Bonding may be accomplished by mechanical, chemical, thermal, or solvent means, or combinations thereof. |
| chemical bonding | A process that uses suitable chemical products to achieve bonding. |
| mechanical bonding | A process that uses suitable mechanical methods to achieve bonding. |
| resin bonding | A process that uses suitable resins or adhesives to achieve bonding. |
| spray bonding | A process that uses droplets of an adhesive sprayed on to the fibre web or batt to achieve bonding. |
| spun bonding /spun laid | A continuous method of making non-woven fabrics in which filaments are extruded and laid down in the form of a web and bonded. |
| stitch bonding | A process that uses suitable stitching techniques to achieve bonding. A stitch-bonded fabric is usually a multicomponent one in which one component is a series of interlooped stitches running along the fabric length, e.g., a fibre web bonded by stitching yarns. |
| heat bonding / thermal bonding | A process in which a web or batt of fibres containing heat-sensitive material is bonded by the application of heat with or without the application of pressure. The heat sensitive material may be in the form of fibres, bicomponent fibres, or powders. |
| Breaking stress | The stress developed in a test specimen at the point of rupture. The force applied is usually related to the cross-sectional area of the unstrained specimen. |
| Breaking tensile strength | See: *strength* |
| Bulk sample | See: *sample* |
| Bursting strength | See: *strength* |
| Calender | A machine in which heavy rollers rotate under mechanical or hydraulic pressure. The rollers may be unheated, or one may be a thick-walled steel shell heated internally. All rollers may rotate at the same speed or one highly polished and heated roller may rotate at a higher surface speed than the rest. |
| Calendering | A method of making a thermal bond in which calender rollers are used to apply heat and pressure, thus causing bonding by the softening or melting of the heat-sensitive material. |
| Capillary barrier | A material or layer that restricts liquid flow under unsaturated conditions through a difference in pore size |

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| Characteristic value | The value of a material property which generally corresponds to a fractile of the assumed statistical distribution of the particular property of the material specified by relevant standards and tested under specific conditions. |
| Chemical bonding | See: *bonding* |
| Chemical resistance | Ability of a material to resist degradation through chemical action |
| Clogging | Blocking of material pores by physical, biological and chemical processes |
| Coefficient of permeability | See: *permeability* |
| Coefficient of variation | The standard deviation expressed as a percentage of the mean value. |
| Composite geotextile | See: *geotextile* |
| Conditioning | The process by which geotextile materials are permitted to come to hygroscopic and thermal equilibrium with the surrounding atmosphere or with the standard atmosphere for testing. (See also standard atmosphere for testing.) |
| Conductivity | Capacity to transmit fluids (liquid and gas) |
| Constant-rate-of-extension | A testing process in which the rate of extension of the specimen is constant with respect to time. Sometimes referred to as using a constant rate of extension (CRE) tensile testing machine. |
| Continuous filament | A fibre of indefinite length. |
| Continuous filament yarn | A yarn of one or more filaments that run essentially the whole length of the yarn. (See also: *filament*)<br>NOTE: Yarns of one or more filaments are usually referred to as monofilament yarns or multifilament yarns respectively. |
| Course | A term applied to knitted fabrics describing a succession or row of knitted loops or stitches across the width of the fabric, usually perpendicular to the wales. (See also wales.) |
| Creep | The time-dependent deformation of a material due to the application of a continuing and constant force. |
| Creep rupture | Delayed rupture of a geosynthetic after a period of time under a constant stress (or load). |
| Cross-machine direction | See: *direction* |
| Cuspated | A sheet that has been indented by a deformation process to form a three dimensional sheet. |
| CRE testing machine | See: *constant-rate-of-extension* |

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| Damage | Reduction in physical properties (e.g. during installation). |
| Degradation | The reduction, over a period of time, in one or more physical properties of a geotextile due to external agencies. Such agencies may include abrasion, heat, weathering, sunlight, ultraviolet light, chemicals, pollutants, soil burial, and various combinations thereof. |
| accelerated degradation | Degradation induced for testing purposes at a rate faster than that applying in normal in-service conditions. |
| actinic degradation | Degradation of fibres or fabrics due to exposure to solar radiation. |
| Denier | A unit of linear density, equal to the mass, in grams, of 9000 m of a filament or yarn. (See also: *linear density and tex*) |
| Diffusion | Flow of fluid due to a gradient of chemical concentration |
| Direction | |
| cross-machine direction | The direction in a machine-made fabric, perpendicular to the direction of motion of the material through the processing machine. |
| machine direction | The direction in a machine-made fabric, parallel to the direction of motion of the material through the processing machine. |
| normal direction | The direction perpendicular to the plane of the geotextile. |
| planar direction | Any direction in the plane of the geotextile. |
| Direct shear test | A test to determine shearing properties along a confined failure plane. |
| Drainage | The collecting and transporting of precipitation, ground water and/or other fluids. |
| Durability | The ability of a geosynthetic to retain its performance over a period of time. (See also degradation.) |
| Drainage composite | see Geocomposite drain. |
| Dynamic loads | Loads changing over time (e.g. seismic, compaction) |
| Earth pressure coefficient | Ratio between horizontal and vertical effective stresses in particulate materials |
| Elastic | Reversible relationship between stress and strain |
| Elastomeric geomembrane | See: *geomembrane, elastomeric* |
| Electrokinetic geosynthetic | A composite material which may provide one or several functions in addition to or in response to electrical conduction. |

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| Electrical leakage detection | A family of methods used to locate perforations in continuous geomembrane sheets |
| Elongation | Extension expressed as a percentage of the original gauge length. |
| Elongation at break | The elongation at the breaking point. |
| Elongation at ultimate force | The elongation at the maximum applied force. |
| EPS foam | Expanded polystyrene foam (see Geofoam) |
| Equivalent opening size | See opening size. |
| Erosion control mat (ECM) | A permeable, biodegradable (synthetic or natural) structure placed over the soil for temporary erosion control applications, usually while vegetation is being established. |
| Extension | The increase of the gauge length with the applied force. |
| Extruded geogrid | See: *geogrid, extruded* |
| Fabric (see: Geotextile) | A manufactured assembly of fibres or yarns or combination of fibres and yarns that has substantial surface area in relation to its thickness and sufficient mechanical strength to give the assembly inherent cohesion. |
| Face surface | The surface of a geotextile fabric, which is normally laid face upwards in the ground, unless designated otherwise. The face surface of a fabric is normally designated by the manufacturer. |
| Fatigue | The phenomenon of change of physical or mechanical properties of a geotextile (usually leading to failure) under the repeated application of a cyclic force. |
| Fibre | A unit of matter characterized by flexibility, fineness, and high ratio of length to thickness. |
| Fibre blinding | The condition where soil particles or other substances accumulate on the surface of a geotextile, thereby reducing its hydraulic properties. (See also filter clogging.) |
| Fibre reinforced soil | A soil that has been mixed with fibres to produce a composite material with enhanced physical properties |
| Filter | A device or material that allows fluid to pass and restrains all or some solid particles from passing. |
| Fifth percentile | The value, calculated from the test results, which is expected to be exceeded by 95 percent of the population values. |
| Filament | See continuous filament. |

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| Film | A polymeric material that is homogeneous, non-fibrous, continuous, thin, and flexible. |
| Filter cake | A layer of soil particles accumulated adjacent to or on the surface of a geotextile. |
| Filtration | See: *functions*. The use of a geosynthetic material to allow passage of fluids from a soil while preventing the uncontrolled passage of soil particles. |
| Fines | The fraction of a soil passing through a 75µm sieve. |
| Flexural modulus | Ratio of the stress difference to the corresponding strain difference during a bending test. Unit: Megapascals (MPa) |
| Flexural strength | Maximum flexural stress sustained by the test specimen during a bending test. Unit: Megapascals (MPa) |
| Flexural stress | Nominal stress of the outer surface of the test specimen at midspan. Unit: Megapascals (MPa) |
| Flow rate | The flow rate per unit area normal to the plane of the product at a defined head. Unit: litres per square metre second (L/m 2.s) |
| Formulation | A specific mixture of components used to create a polymer or a polymer blend used to make a geosynthetic. |
| Force | That which can alter the state of rest or motion of a body.<br><br>Unit: newton (N), kilonewton (kN) NOTE: 1 N = 1 kg.m/s2. Thus, at the surface of the earth, a mass of 100 kg exerts a force of approximately 980 N. |
| breaking force | The maximum force applied to a test specimen at the point of rupture. |
| peak force | The force at which strain first increases with no increase in force. (See point P on Figure A4, Appendix A.) |
| ultimate force | The maximum force applied to the test specimen in a tensile test carried out to failure. (See point U on Figure A4, Appendix A.) |
| Friction | Resistance to shear deformation from surface interaction. |
| Friction coefficient | The ratio of the friction force per unit area to the normal stress between two materials. It is said to be the tangent of the interface friction angle. |
| Gauge length | In tensile testing, the initial length of a test specimen measured between the specimen clamps. |
| Geoarmour | A permeable geosynthetic material placed over the surface of the soil, in conjunction with pattern-placed block armour units, to prevent erosion. |

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| Geoblanket | A permeable, biodegradable (synthetic or natural) structure placed over the soil for temporary erosion control applications, usually while vegetation is being established |
| Geocell | A three-dimensional, permeable, polymeric (synthetic or natural) honeycomb or web structure, made of strips of geotextiles, geogrids or geomembranes linked alternatingly and used in contact with soil/rock and/or any other geotechnical material in civil engineering applications |
| Geocomposite | A manufactured or assembled material using at least one geosynthetic product among the components, used in contact with soil/rock and/or any other geotechnical material in civil engineering applications |
| Geocomposite clay liner | An assembled structure of geosynthetic materials and low hydraulic conductivity earth materials (clay or bentonite), in the form of a manufactured sheet, used in civil engineering applications. |
| Geocomposite drain | A prefabricated subsurface drainage product which consists of a geotextile filter skin supported by a geonet or a geospacer |
| Geocomposite reinforcement | An assembled structure of dissimilar geosynthetic materials used for soil reinforcement |
| Geofoam | A polymeric material which has been formed by the application of the polymer in semi-liquid form, through the use of a foaming agent, and results in a lightweight material with high void content, used in civil engineering applications. |
| Geoform | A three-dimensional, permeable geosynthetic structure, filled with soil or sediment waste such that the fill takes the shape of the inflated geoform |
| Geogrid | A planar, polymeric structure consisting of a regular open network of integrally connected tensile elements, which may be linked by extrusion, bonding or interlacing, whose openings are larger than the constituents, used civil engineering applications (primarily for reinforcement applications). |
| geogrid, bonded | A geogrid manufactured by bonding, usually at right angles, two or more sets of strands or elements. |
| geogrid, extruded | A geogrid manufactured by extruding polymers and drawing in a sheet form. |
| geogrid, knitted | A geogrid manufactured by knitting together yarns or elements, usually at right angles to each other. |
| geogrid, woven | A geogrid manufactured by weaving yarns or elements, usually at right angles to each other. |

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| Geomat<br>(See also: erosion control mat and turf reinforcement mat) | A three-dimensional, permeable, polymeric structure, made of bonded filaments, used to reinforce roots of grass and small plants and extend the erosion-control limits of vegetation for permanent erosion control applications. |
| Geomattress | A three-dimensional, permeable geosynthetic structure, placed over the surface of a soil, and then filled with concrete mortar or soil. |
| Geomembrane | A planar, relatively impermeable, polymeric (synthetic or natural) sheet used in civil engineering applications. |
| geomembrane, bituminous | A geomembrane manufactured from natural bituminous materials. |
| geomembrane, elastomeric | A geomembrane manufactured from elastomeric polymers. |
| geomembrane, plastomeric | A geomembrane manufactured from plastomeric polymers. |
| Geonet | A planar, polymeric structure consisting of a regular dense network, whose constituent elements are linked by knots or extrusions and whose openings are much larger than the constituents, used in civil engineering applications. |
| Geopipe | A buried pipe made from polymeric material |
| Geospacer | A three-dimensional polymeric structure with large void spaces, used in civil engineering applications. |
| Geostrip | A polymeric material in the form of a strip, used in civil engineering applications. |
| Geosynthetic | A polymeric (synthetic or natural) material used in contact with soil/rock and/or any other geotechnical material in civil engineering applications. |
| Geosynthetic clay liner (GCL) | An assembled structure of geosynthetic materials and low hydraulic conductivity earth material (clay), in the form of a manufactured sheet, used in civil engineering applications. |
| Geotechnical engineering | The engineering applications of geotechnics. |
| Geotechnics | The application of scientific methods and engineering principles to the acquisition, interpretation, and use of knowledge of materials of the earth's crust to the solution of engineering problems.<br><br>NOTE: Geotechnics embraces the fields of soil mechanics and rock mechanics, and many of the engineering aspects of geology, geophysics, hydrology, and related sciences. |

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| Geotextile | A planar, permeable, polymeric (synthetic or natural) textile material, which may be nonwoven, knitted or woven, used in contact with soil/rock and/or any other geotechnical material in civil engineering applications. |
| geotextile, knitted | A geotextile produced by interlooping one or more yarns, fibres, filaments or other elements. |
| geotextile, nonwoven | A geotextile in the form of a manufactured sheet, web or batt of directionally or randomly orientated fibres, filaments or other elements, mechanically and/or thermally and/or chemically bonded. |
| geotextile, woven | A geotextile produced by interlacing, usually at right angles, two or more sets of yarns, fibres, filaments, tapes or other elements. |
| Geotextile bags | See Geocontainers |
| Geocontainers | A geosynthetic container filled with soil or other material |
| Geotubes | See Geocontainer |
| Hydration | Absorption of liquid |
| Hydraulic gradient | The ratio of the total head loss ($\Delta h$) across the specimen to its length ($l$) in the flow direction. |
| Hydrolysis | The cleavage of chemical bonds in polymers by reaction with water, including moisture or steam.<br><br>NOTE: Polar linkages in polymers such as ester, amide and urethane bridges are particularly susceptible to hydrolysis. For this reason polyesters, polyamides and polyurethanes are all sensitive to hydrolysis in moist, warm environments. Hydrolysis is generally acid or base catalyzed. |
| Inclined plane test | A shear test performed by increasing the inclination of the plane |
| Interface shear strength | The shear strength at a given interface generated by a combination of cohesion (adhesion) and friction forces. The interface may be internal (e.g. for a soil) or it may be at an external interface with another material. |
| Interface adhesion | Shear strength at an interface at zero normal stress |
| Interface friction angle | An angle, the tangent of which is equal to the ratio of the friction force per unit area to the normal stress between two materials. |
| Interface peak shear strength | Maximum values of the curve of interface shear strength obtained as a function of deformation. |

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| Interface residual shear strength | Interface shear strength obtained at large deformation. |
| Isochronous curve | The result of re-plotting a series of standardised load-dependent geosynthetic strain versus time curves into a series of time-dependent load versus strain curves, demonstrating the achieved strain specific to a given time. |
| Isotropic | Having the same physical properties in every direction in the plane of the geosynthetic. |
| Limit state design | Design that meets requirements to guarantee the limit state performance (see ultimate and serviceability limit states). |
| Linear density | The mass per unit length of linear textile material (yarn or fibre). (See also tex.) |
| Locknit | A fabric made on a warp knitting machine in which the stitches are interlocked in a manner that resists runs in the fabric. |
| Lot | Group of items of a single type with specific characteristics and dimensions, presented for sampling at the same time. |
| Knitted geogrid | See: *geogrid, knitted* |
| Knitted geotextile | See: *geotextile, knitted* |
| Mass per unit area | The ratio of the mass of a specimen of specified dimensions to its area. Unit: grams per square metre ($g/m^2$). |
| Mean value | The arithmetic mean of a set of test results. |
| Man-made fibre | A fibre manufactured by man as distinct from a fibre that occurs naturally. |
| MARV (minimum average roll value) | A statistical value defined as the mean minus two standard deviations. |
| Monofilament | A single relatively thin and flexible continuous strand of polymer or polymers. (See also: *fibre*) |
| Multifilament | A yarn composed of more than one continuous filament or strand. |
| Needle felt | A non-woven structure formed by the mechanical bonding of a fibre web or batt by needling. (See also: *bonding—needle bonding*) |
| Ninety-fifth percentile | The value, calculated from the test results, which 95 percent of population values are expected to exceed. |
| Nonwoven geotextile | See: *geotextile, nonwoven* |

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| Nominal value | The value of a material property as declared, rather than measured, by the producer/supplier of the material. |
| OIT test | Oxidation induction time test which is used to measure relative resistance to oxidation |
| Open area | That percentage of the total area of the geotextile measured in the plane of the geotextile in which there are no fibres, filaments, or films between its upper and lower surfaces. |
| Opening size | |
| apparent opening size | The particle size of a standard sand fraction for which a specified percentage by mass would be retained as determined by the dry sieving method.<br>NOTE: The quantity symbol is $O_n$, where n is the specified percentage.<br>Abbreviation: AOS Unit: micrometre (µm) |
| equivalent opening size | The particle size of a standard sand fraction for which 95% by mass would be retained as determined by the dry sieving method.<br><br>Abbreviation: EOS. Quantity symbol: O95<br><br>Unit: micrometre (µm) |
| Order | A quantity of geosynthetic, of the same material and grade, ordered on one occasion for the one project. |
| Oriented tape slit film | A tape produced by extruding a thermoplastic polymer in the form of a sheet or film, slitting the film into tapes and hot stretching to induce molecular orientation and, hence, high longitudinal strength. |
| Overlay | A material that is laid over another material to provide enhanced performance or protection |
| Oxidation | The chemical reaction of oxygen with polymers due to exposure of the polymer to oxidizing chemicals (e.g., oxidizing acids or peroxides), or to oxygen plus elevated temperatures, UV light or ionizing radiation (or combination thereof, such as in weathering).<br><br>Note: Oxidation proceeds by a free radical mechanism and ultimately leads to degradation of the polymer (either by lowering of the molecular weight or by cross-linking) and consequently loss of useful mechanical properties. |
| Partial factors | Application of factors to determine increased loads or decreased resistances (e.g. reduction of a soils properties) |

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| Coefficient of permeability | A measure of the permeability of a geotextile to water. For uniform laminar flow, it is equal to the ratio of the outflow velocity to the average hydraulic gradient at a standard fluid temperature.<br>Unit: metre per second (m/s). |
| Permittivity | The volumetric flow rate of water per unit cross-sectional area per unit head, under laminar conditions of flow, in the normal direction through a geotextile. (See also transmissivity.)<br><br>Unit: reciprocal second ($s^{-1}$). |
| Piezometric tube | A vertical tube, open to the atmosphere, used to measure hydrostatic pressure. |
| Piping | The process whereby soil particles migrate through a filter owing to the passage of water. |
| Plane strain | A strain condition of a material in which the strain in the orthogonal direction is zero (i.e. used in modeling two-dimensional situations) |
| Plastic behaviour | Mechanical behaviour characterised by irreversible relationship between stress and strain |
| Polymer | A large molecule built up by the repetition of small simple chemical units called monomers. In man-made fibres, a chain-like structure of high molecular mass produced by linking together monomeric units consisting predominantly of non-metallic elements or compounds. |
| Pores | The voids in a geotextile. |
| Pore size distribution | The distribution of pore sizes in a geotextile.<br>Often stated in terms of opening sizes determined by a standard test for the diameter of particles passing through. (See also opening size.) |
| Porometry | Measurement of sizes of pores and study of their distribution. |
| Plastomeric geomembrane | See: *geomembrane, plastomeric* |
| Porosity | The ratio of the volume of void spaces to the total volume of a geotextile.<br>NOTE: Porosity is usually expressed as a percentage. |
| Preload | A small load equal to 1% of the expected maximum load, enabling initial gauge length and strain zero to be determined under reproducible conditions. |
| Protection | The preventing or limiting of local damage to a given element or material by the use of a geotextile or a geotextile-related product. |

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| Pull-out test | A test to quantify interaction between a geosynthetic and a confining soil under pull-out conditions |
| Puncture | The rupture of a geotextile by a localized force normal to the plane of the geotextile while the geotextile is constrained in all directions in that plane. |
| PVD | Prefabricated vertical drain. See vertical drain |
| RECP<br>(rolled erosion control product) | See: *erosion control mat (ECM)* |
| Reduction factor | A factor applied to reduce a design property in the face of potential uncertainty over its measurement or assessment. |
| Regenerated fibre | A man-made fibre produced from a naturally occurring fibre-forming polymer by a process that includes regeneration of the original polymer structure. |
| Reinforcement | The use of the stress-strain behaviour of a geosynthetic to improve the mechanical properties of soil or other construction materials. |
| Representative values | Values for material properties obtained from a number of individual specimens. Unless otherwise stated, these include the sample mean and standard deviation, and may include the fifth or ninety-fifth percentile value. |
| Resilient modulus | Modulus of soil obtained after a large number of loading cycles |
| Roll | A unit of production. |
| Sample | One or more items taken as representative of a population, or portion of material taken without bias from a bulk material for assessment. |
| bulk sample | A random selection of one or more rolls of geotextile taken from the batch or order in accordance with the batch or order size. |
| laboratory sample | A portion of material taken to represent the bulk sample or the bulk sample itself and used in the laboratory as a source of test samples or test specimens. |
| test sample | A sample as prepared for testing. It may consist of one or more test specimens.<br>NOTE: As a general rule this is a part of the laboratory sample, prepared in such a manner as to retain its representative character; however, in certain cases it may consist of the whole laboratory sample. |
| Seam | The joint between sections of geosynthetics produced by means of sewing, welding, gluing or other means. |

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| Scrim | A general term, irrespective of structure, for a lightweight basecloth included in a non-woven fabric. (See also basecloth.) |
| Separation | That function of a geotextile by which adjacent dissimilar materials are prevented from intermixing. |
| Serviceability limit state | Limit state related to the function of the structure under normal use (see limit state design) |
| Service life | The period of time after which the material or structure ceases to provide its intended function at the required level of safety |
| Shrinkage | A reduction in dimension |
| Soil-filter zone | A zone Of Soil Stratification Adjacent To A Geotextile Created By Fluid Flow Through The Soil-Geotextile System. |
| Soil-geosynthetic friction | A measure of the shear force per unit area required to cause slippage of a geosynthetic over one layer or from between several layers of soil. |
| Specimen | |
| test specimen | A specific portion of a material or a laboratory specimen upon which a test is performed or which is selected for that purpose. |
| Standard atmosphere for testing | An atmosphere at the prevailing barometric pressure with a relative humidity of 65 ±3% at a temperature of 23 ±5°C. |
| Standard Deviation | A statistical measure of the variability of a set of results. |
| Staple fibre | A man-made fibre of predetermined short length. The fibre is usually prepared by cutting or breaking filaments of the material into lengths suitable for the processing system in question. Lengths usually range from 5 mm to 500 mm. |
| Stepped isothermal method | A method of exposure that uses temperature steps and dwell times to accelerate creep response of a material being tested under load. |
| Stiffness | Relationship between strain and stress for a material. |
| Strain | The ratio of extension to original gauge length. (See also elongation.) |
| Strength | |
| breaking tensile strength | The force per unit specimen width applied in the plane of the geotextile at the point of rupture or breaking point. Unit: newton/unit width (N/unit width), kilonewton/unit width (kN/unit width.) |
| peak tensile strength | The tensile strength corresponding to the first peak on the force/elongation curve of a tensile strength test. (See point P on Figure A4, Appendix A.) |

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| tearing strength | The force required to continue or propagate a tear in a geosynthetic material.<br>Unit: newton (N), kilonewton (kN) |
| tensile strength | The force per unit specimen width applied in the plane of the geosynthetic.<br>Unit: newton (N), kilonewton (kN) |
| ultimate tensile strength | The maximum tensile strength corresponding to the highest peak on the force/elongation curve of a tensile strength test. (See point U on Figure A4, Appendix A.) |
| yield tensile strength | The tensile strength corresponding to the yield point on the force/elongation curve of a tensile strength test. |
| Stress crack | Crack initialisation in a crystalline polymeric material |
| Surface erosion control | The use of a geosynthetic to prevent or limit soil or other particle movements at the surface of, for example, a slope. |
| Synthetic fibre | A man-made fibre produced from a polymer built up by man from chemical elements or compounds, in contrast to fibres made from naturally occurring fibre-forming polymers. |
| Tape<br>(thin slit film)<br>(See: fibre.) | A yarn having a very large width-to-thickness ratio, and usually formed by slitting a wide film into individual tapes with hot stretching either before or after slitting. |
| Tenacity | The ultimate tensile strength of a fibre or yarn expressed as force per unit linear density of the unstrained specimen. (See also linear density.)<br>Unit: millinewton per tex (mN/tex) |
| Tensile stress,<br>related to the cross-sectional area of specimen | The tensile force per cross-sectional area of the specimen prior to loading (typically MPa), carried by a specimen at any given time in a short-term test. |
| Tensile test | A test in which a geotextile material is loaded to determine its force/elongation characteristics. |
| grab tensile test | A uniaxial tensile test in which only the central portion of the specimen is gripped in the jaws. |
| plane-strain tensile test | A uniaxial tensile test in which the entire width of the specimen is gripped in the jaws with the specimen being restrained from deforming laterally. |

| | |
|---|---|
| wide strip tensile test | A uniaxial tensile test in which the entire width of the specimen is gripped in the jaws and in which the specimen width is greater than the gauge length. |
| tensile modulus | The ratio of the change in tensile force per unit width of the geotextile to the change in corresponding elongation.<br>Unit: kilonewton per metre (kN/m) |
| initial tensile modulus | The slope of the initial portion of a force per unit width/elongation curve. (See line AG in Figure A1, Appendix A.) |
| offset tensile modulus | The maximum value of the tangent modulus. (See line BD in Figure A1, Appendix A.) |
| secant tensile modulus | The ratio of change in force per unit width to change in elongation between two points on a force per unit width/elongation curve, particularly the points of zero force and a specified percent elongation. (See lines QR and AM in Figure A3, Appendix A.) |
| tangent tensile modulus | The slope of the force/elongation curve at any given elongation. |
| Test result | The result from a single measurement on one specimen. |
| Tex | The unit of linear density used in the textile industry. 1 tex = 10−6 kg/m = 1 g/km (See also linear density.) |
| Textile | Man-made fabric, produced by either weaving, needle punching or bonding fibres or filaments.<br>NOTE: Examples of textiles are threads, cords, ropes, braids, lace, embroidery, nets, and fabrics mad e by weaving, knitting, felting, bonding, and tufting are all textiles. |
| Texture | Roughness of a geosynthetic surface |
| Thermal degradation | Reduction in physical properties resulting from thermal effects |
| Thermal stress | Stress change induced by thermal strain |
| Thermo-oxidation | Accelerated oxidation due to thermal effects |
| Thickness | The distance between the upper and lower surfaces of a geosynthetic, measured normal to the surfaces and under a specified pressure. |
| Toughness | The property of a geotextile by virtue of which it can absorb energy. It is expressed as the actual work-to-break per unit surface area and is proportional to the area under the force/elongation curve from origin to rupture point. |

| | |
|---|---|
| Transmissivity | The ability of a geosynthetic to conduct a fluid within its plane . It is expressed as the product of the coefficient of permeability in the geosynthetic plane and the thickness of the geosynthetic. (See also permittivity.) Unit: square metre per second ($m^2/s$) |
| Turf reinforcement mat (TRM) | A three-dimensional, permeable, polymeric structure made of bonded filaments, used to reinforce roots of grass and small plants and extend the erosion-control limits of vegetation for permanent erosion control applications. |
| Ulitimate limit state | The limit state of a structure that concerns safety of people and/or the safety of the structure |
| Uniaxial | Testing or performance that takes place in one direction |
| Vertical drain | A drain inserted vertically into a soil to provide drainage in order to accelerate consolidation. |
| Viscosity | Measure of resistance of a liquid to being deformed by stress |
| Void ratio | The ratio of the volume of void space to the volume of solids in a geotextile.<br>NOTE: In a geotextile, the solids are considered to be incompressible, and include fibres, yarns, binders, and combinations thereof, if present. |
| Wale | In knitted fabrics, a column of loops in successive courses and perpendicular to them. (See also course.) |
| Warp | Yarns, filaments, or tapes running in the machine direction of the weaving machine or loom. |
| Weft | Yarns, filaments, or tapes running at 90° to the machine direction of the weaving machine or loom. |
| Woven geogrid | See: *geogrid, woven* |
| Woven geotextile | See: *geotextile, woven* |
| Wrinkle | Deviation from planarity of a sheet (e.g. a small ridge) typically by shrinkage and contraction |
| Yarn | A generic term for a continuous strand of textile fibres, filaments,or other materials in a form suitable for weaving or otherwise intertwining to form a textile fabric. |

# 3. Mathematical Symbols

## 3.1 General symbols

### 3.1.1 Dimensions

Symbols used for dimensions are:

| | |
|---|---|
| L | Length |
| M | Mass |
| t | Time |
| T | Temperature |
| - | Dimensionless |

### 3.1.2 Units

| | |
|---|---|
| m | Metre |
| $m^2$ | square metre |
| $m^3$ | cubic metre |
| km | kilometre = $10^3$ m |
| mm | millimetre = $10^{-3}$ m |
| μm | micrometre or micron = $10^{-6}$ m |
| g | Gram |
| mg | milligram = $10^{-3}$ g |
| kg | kilogram = $10^3$ g |
| Mg | megagram = $10^6$ g = tonne |
| s | Second |
| N | Newton |
| kN | kilonewton = $10^3$ N |
| Pa | pascal = $N/m^2$ |
| kPa | kilopascal = $kN/m^2$ |
| MPa | megapascal = $MN/m^2$ |
| j | joule = Nm |
| tex | tex = $10^{-6}$ kg/m = mg/m |
| j/kg | tenacity = $10^{-6}$ N/tex |
| ° | Degree |
| % | Percent |
| - | pure number |

### 3.1.3 Prefixes for units

| | |
|---|---|
| G | giga = $10^9$ |
| M | mega = $10^6$ |
| k | kilo = $10^3$ |

| | |
|---|---|
| c | centi = $10^{-2}$ |
| m | milli = $10^{-3}$ |
| μ | micro = $10^{-6}$ |
| n | nano = $10^{-9}$ |

### 3.1.4 Recommended subscripts

| | |
|---|---|
| a | air, active (earth pressure), allowed |
| B | Base |
| cr | creep reduction |
| cv | constant volume or critical state |
| d | dry state, diameter, design |
| f | failure, fibre, filament, final |
| GSY | geosynthetic material, e.g. $t_{GSY}$ is thickness of geosynthetic material |
| GBA | Geobar |
| GBL | Geoblanket |
| GCE | Geocell |
| GCD | geocomposite drain |
| GCL | geocomposite clay liner |
| GEC | geosynthetic erosion control material |
| GEK | electrokinetic geosynthetic |
| GFO | Geofoam |
| GFR | Geoform |
| GGR | Geogrid |
| GMA | Geomat |
| GMB | Geomembrane |
| GMT | Geomattress |
| GNT | Geonet |
| GSP | Geospacer |
| GST | Geostrip |
| GTX | Geotextile |
| GTXw | woven geotextile |
| GTXnw | nonwoven geotextile |
| h | horizontal |
| i | immediate, initial |
| j | Joint |
| k | characteristic, e.g. $T_{max,k}$ is characteristic maximum tensile strength |
| m | Material |
| max | Maximum |
| min | Minimum |
| mr | material reduction |

| | |
|---|---|
| n | normal, number |
| p | passive (earth pressure), planar, pullout |
| r | radial, resistance, residual |
| req | Required |
| s | solid particles, sliding |
| sat | Saturated |
| sec | Secant |
| u | undrained conditions |
| v | Vertical |
| w | Water |
| *x*, y | two orthogonal horizontal axes |
| *z* | vertical axis |
| $\varepsilon$ | at specific strain or elongation |
| 0 | at rest (earth pressure), zero |
| 1,2,3 | principal directions |

### 3.1.5 Geometry and kinetics

| | | | |
|---|---|---|---|
| *A* | $L^2$ | ($m^2$) | Area |
| *b*, *B* | L | (m) | breadth or width |
| *d* | L | (m) | Diameter |
| *D* | L | (m) | Depth |
| *g* | $Lt^{-2}$ | ($m/s^2$) | acceleration due to gravity g = 9.8 $m/s^2$ |
| *H* | L | (m) | Height |
| *l*, *L* | L | (m) | Length |
| *t* | t | (s) | Time |
| *v* | $Lt^{-1}$ | (m/s) | Velocity |
| *V* | $L^3$ | ($m^3$) | Volume |

## 3.2 Properties related to geosynthetics

### 3.2.1 Physical properties

| | | | |
|---|---|---|---|
| $t_{GTX}$ | L | (mm) | thickness of GTX, etc. |
| $b_{GTX}$ | L | (m) | width of GTX, etc. |
| $\rho_f$ | $ML^{-3}$ | ($Mg/m^3$) | density of fibres or filaments (mass per unit volume) |
| $\mu_A$ | $ML^{-2}$ | ($g/m^2$) | mass per unit area |
| $d_f$ | L | ($\mu m$) | diameter of fibres or filaments |
| $\lambda$ | ML | (tex) | linear density of yarns, fibres, filaments |
| *A* | - | (%) | percent open area for wovens or geogrids |
| $n_{GTX}$ | - | | porosity (ratio between volume of voids & total volume) of a GTX |

### 3.2.2 Hydraulic properties

| | | | |
|---|---|---|---|
| $O_n$ | L | (mm, μm) | *n* percent opening size of a GTX - generic term |
| $O_{n,d}$ | L | (mm, μm) | *n* percent opening size as measured by a dry sieving test, e.g. $O_{90,d}$, $O_{95,d}$. Sometimes referred to AOS or EOS |
| $O_{95,d}$ | L | (mm, μm) | Equivalent Opening Size (EOS) corresponding to the 95% opening size measured by a dry sieving test |
| $O_{n,w}$ | L | (mm, μm) | *n* percent opening size as measured by a wet sieving test, e.g. $O_{90,w}$, $O_{95,w}$. Sometimes referred to $D_w$ or $d_{95}$ |
| $q_n$ | $LT^{-1}$ | (litres/$m^2$.s) | flow capacity normal to the plane of a GTX - generic term. |
| $q_{n,h}$ | $LT^{-1}$ | (litres/$m^2$.s) | flow capacity normal to the plane of a GTX under water head *h* (in mm), e.g. $q_{n,100}$ is flow capacity normal to the plane under water head of 100mm. |
| $q_p$ | $L^2T^{-1}$ | (litres/m.s) | flow capacity within the plane of a GTX, GNE or GCD - generic term. |
| $q_{p,i}$ | $L^2T^{-1}$ | (litres/m.s) | flow capacity within the plane of a GTX, GNE or GCD under hydraulic gradient *i*, e.g. $q_{p,1}$ is flow capacity within the plane under hydraulic gradient of 1. |
| $k_n$ | $Lt^{-1}$ | (m/s) | Coefficient of permeability normal to the plane |
| $k_p$ | $Lt^{-1}$ | (m/s) | Coefficient of permeability in the plane of a GTX or GCD |
| $\psi$ | $t^{-1}$ | ($s^{-1}$) | permittivity of a GTX. $\psi = k_n/t_{GTX}$ |
| $\theta$ | $L^2t^{-1}$ | ($m^2$/s) | transmissivity of a GTX or GCD. $\theta = k_p\, t_{GTX}$ |
| $\psi'$ | $t^{-1}$ | ($s^{-1}$) | permittivity of a GMB to vapour flow (permeance). It is the rate of vapour transmission divided by the vapour pressure difference across the GMB. |
| $k'_n$ | $Lt^{-1}$ | (m/s) | vapour permeability of a GMB normal to its plane. $k'_n = \psi' t_{GMB}$ |

### 3.2.3 Mechanical properties

| | | | |
|---|---|---|---|
| $\varepsilon$ | - | (%) | strain or elongation |
| $\varepsilon'$ | $t^{-1}$ | (%/s) | strain rate |
| $\varepsilon_f$ | - | (%) | strain or elongation at failure |
| $\varepsilon_{max}$ | - | (%) | maximum strain or elongation |
| $T$ | $Mt^{-2}$ | (kN/m) | tension (tensile strength per unit width) |
| $T_\varepsilon$ | $Mt^{-2}$ | (kN/m) | tension at a given elongation $\varepsilon$; e.g. $T_{30}$ is the tension at 30% elongation |
| $T_f$ | $Mt^{-2}$ | (kN/m) | tension at failure |
| $T_{max}$ | $Mt^{-2}$ | (kN/m) | maximum tension |
| $T_a$ | $Mt^{-2}$ | (kN/m) | allowable tension |
| $T_B$ | $Mt^{-2}$ | (kN/m) | base tension in a geosynthetic reinforcement after allowing for the effects of creep. Sometimes referred to as creep-limited strength |
| $T_{req}$ | $Mt^{-2}$ | (kN/m) | Required tension |
| $J$ | $Mt^{-2}$ | (kN/m) | tensile stiffness |
| $J_\varepsilon$ | $Mt^{-2}$ | (kN/m) | tangential tensile stiffness at elongation $\varepsilon$ |

| | | | |
|---|---|---|---|
| $J_i$ | $Mt^{-2}$ | (kN/m) | initial tensile stiffness (at $\varepsilon$ = 0%) |
| $J_{sec\ \varepsilon}$ | $Mt^{-2}$ | (kN/m) | secant tensile stiffness between the origin and elongation $\varepsilon$; e.g. $J_{sec30}$ is the secant tensile stiffness between elongation $\varepsilon$= 0 and $\varepsilon$= 30% |
| $J_{secn,m}$ | $Mt^{-2}$ | (kN/m) | secant tensile stiffness between $\varepsilon$= n% and $\varepsilon$= m% elongation. |
| $\sigma_\varepsilon$ | $ML^{-1}t^{-2}$ | (kN/m$^2$, kPa) | tensile stress at elongation $\varepsilon$; e.g. $\sigma_{30}$ is the tensile stress at 30% elongation |
| $\sigma_{max}$ | $ML^{-1}t^{-2}$ | (kN/m$^2$, kPa) | maximum tensile stress |
| $\sigma_f$ | $ML^{-1}t^{-2}$ | (kN/m$^2$, kPa) | tensile stress at failure |
| $E$ | $ML^{-1}t^{-2}$ | (kN/m$^2$, kPa) | elastic modulus |
| $E_i$ | $ML^{-1}t^{-2}$ | (kN/m$^2$, kPa) | initial tangential modulus (see $J_i$) |
| $E_\varepsilon$ | $ML^{-1}t^{-2}$ | (kN/m$^2$, kPa) | tangential modulus at elongation $\varepsilon$ (see $J_\varepsilon$) |
| $E_{sec\ \varepsilon}$ | $ML^{-1}t^{-2}$ | (kN/m$^2$, kPa) | secant modulus between the origin and elongation $\varepsilon$ (see $J_{sec\ \varepsilon}$) |
| $\nu$ | - | | poisson's ratio |
| $\zeta_y$ | $L^2t^2$ | (N/tex) | tenacity of a yarn (ratio between tensile strength of a yarn and its linear density) |
| $\xi$ | (varies) | | mechanical efficiency (ratio between maximum strength and mass per unit area) |
| $F_f$ | $MLt^{-2}$ | (N, kN) | load recorded at failure in a tensile test (NB: the tensile test must be specified) |
| $F_{max}$ | $MLt^{-2}$ | (N, kN) | maximum tensile force of a GT or GM (NB: the tensile test must be specified) |
| $F_G$ | $MLt^{-2}$ | (N, kN) | breaking force as measured in a Grab test (NB: the Grab test must be specified) |
| $F_P$ | $MLt^{-2}$ | (N, kN) | breaking force in a static puncture test (NB: the static puncture test must be specified) |
| $F_T$ | $MLt^{-2}$ | (N, kN) | breaking force in a tear propagation test (NB: the tear propagation test must be specified) |
| $O_{dc}$ | L | (mm) | perforation resistance in a dynamic tear initiation test (NB: the tear initiation test must be specified) |
| $P_r$ | $Mt^{-2}$ | (kN/m) | pullout resistance |
| $p_B$ | $ML^{-1}t^{-2}$ | (kN/m$^2$, kPa) | bursting pressure (NB: the burst test must be specified) |
| $W_I$ | $ML^2t^{-2}$ | (Joules) | energy measuring the resistance in an impact test (NB: the impact test must be specified) |

### 3.2.4 Interface properties

| | | | |
|---|---|---|---|
| $f_{s/GSY}$ | - | (-) | friction interaction coefficient between soil and GSY. $f_{s/GSY}$ tan $\phi' = \tan \phi'_{s/GSY}$.$\phi'$ is friction angle of soil. |
| $\mu_{s/GSY}$ | - | (-) | coefficient of friction between soil and GSY. $\mu_{s/GSY} = \tan \phi'_{s/GSY}$ and $\mu_{s/GSY} = f_{s/GSY} \tan \phi'$. |
| $\phi'_{s/GSY}$ | - | (°) | effective friction angle between soil and GSY - general term. |
| $\phi'_{p,\ s/GSY}$ | - | (°) | effective peak friction angle between soil and GSY. |
| $\phi'_{r,\ s/GSY}$ | - | (°) | effective large strain friction angle between soil and GSY. |

## 3.3 Properties related to fluids

### 3.3.1 Physical properties

| | | | |
|---|---|---|---|
| $\rho_w$ | $ML^{-3}$ | ($Mg/m^3$) | density of water (mass per unit volume) |
| $\gamma_w$ | $ML^{-2}t^{-2}$ | ($kN/m^3$) | unit weight of water (weight per unit volume) |
| $\eta_w$ | $ML^{-1}t^{-1}$ | (kg/ms) | dynamic viscosity of water |

### 3.3.2 Flow properties

| | | | |
|---|---|---|---|
| $h$ | L | (m) | hydraulic head or potential |
| $Q$ | $L^3t^{-1}$ | ($m^3/s$) | rate of discharge (also called flow rate) - volume of water passing through a given area per unit of time |
| $v$ | $Lt^{-1}$ | (m/s) | discharge velocity |
| $i$ | - | | hydraulic gradient |
| $j$ | $ML^{-2}t^{-2}$ | ($kN/m^3$) | seepage force per unit volume (force per unit volume of a porous medium generated by action of fluid upon the solid elements of the porous medium). $j = i\ \gamma_w$ |

## 3.4 Properties related to geotechnics

### 3.4.1 Physical properties

#### 3.4.1.1 Solid particles and their distribution

| | | | |
|---|---|---|---|
| $\rho_s$ | $ML^{-3}$ | ($Mg/m^3$) | density of solid particles (ratio between mass and volume of solid particles) |
| $\gamma_s$ | $ML^{-2}t^{-2}$ | ($kN/m^3$) | unit weight of solid particles (weight of solid particles per unit volume). $\gamma_s = \rho_s\ g$ |
| $d$ | L | (μm, mm) | particle diameter |
| $d_n$ | L | (μm, mm) | $n$ percent diameter (diameter corresponding to $n$% by weight of finer particles) |
| $C_u$ | - | | uniformity coefficient. $C_u = d_{60}/d_{10}$ |

#### 3.4.1.2 Density of soils

| | | | |
|---|---|---|---|
| $\rho$ | $ML^{-3}$ | ($Mg/m^3$) | density of soil (ratio between total mass and total volume of soil) |
| $\gamma$ | $ML^{-2}t^{-2}$ | ($kN/m^3$) | unit weight of soil (ratio between total weight and total volume of soil). $\gamma = \rho\ g$ |
| $\rho_d$ | $ML^{-3}$ | ($Mg/m^3$) | density of dry soil (ratio between mass of solid particles and total volume of soil) |
| $\gamma_d$ | $ML^{-2}t^{-2}$ | ($kN/m^3$) | unit weight of dry soil (ratio between weight of solid particles and volume of soil). $\gamma_d = \rho_d\ g$ |
| $\rho_{sat}$ | $ML^{-3}$ | ($Mg/m^3$) | density of saturated soil (ratio between total mass and total volume of completely saturated soil) |

| | | | |
|---|---|---|---|
| $\gamma_{sat}$ | $ML^{-2}t^{-2}$ | ($kN/m^3$) | unit weight of saturated soil (ratio between total weight and total volume of completely saturated soil). $\gamma_{sat} = \rho_{sat}\, g$ |
| $\rho'$ | $ML^{-3}$ | ($Mg/m^3$) | density of submerged soil (difference between density of soil and density of water). $\rho' = \rho - \rho_w$ |
| $\gamma'$ | $ML^{-2}t^{-2}$ | ($kN/m^3$) | unit weight of submerged soil (difference between unit weight of soil and unit weight of water). $\gamma' = \gamma - \gamma_w = \rho'\, g$ |

### 3.4.1.3 Voids and water in soils

| | | | |
|---|---|---|---|
| $e$ | - | (-) | void ratio (ratio between volume of voids and volume of solid particles) |
| $n$ | - | (%) | porosity (ratio between volume of voids and total volume of soil) |
| $w$ | - | (%) | water content (ratio between weight of pore water and weight of solid particles) |
| $S_r$ | - | (%) | degree of saturation (ratio between volume of pore water and volume of voids) |

### 3.4.1.4 Consistency of soils

| | | | |
|---|---|---|---|
| $w_L$ | - | (%) | liquid limit (water content of a remoulded soil at transition between liquid and plastic states, determined by a standard laboratory test) |
| $w_P$ | - | (%) | plastic limit (water content of a remoulded soil at transition between plastic and semi-solid states, determined by a standard laboratory test) |
| $w_S$ | - | (%) | shrinkage limit (maximum water content at which a reduction of water content will not cause a decrease in volume of the soil mass) |
| $I_P$ | - | (%) | plasticity index (difference between liquid and plasticity limits) |
| $I_L$ | - | (%) | liquidity limit, defined as $(w - w_P)/I_P$ |
| $I_C$ | - | (%) | Consistency index, defined as $(w_L - w)/I_P$ |
| $e_{max}$ | - | (-) | void ratio in loosest state (maximum void ratio obtainable by a standard laboratory procedure) |
| $e_{min}$ | - | (-) | void ratio in densest state (minimum void ratio obtainable by a standard laboratory procedure) |
| $I_D$ | - | (-) | density index (also called 'relative density', $R_D$). $I_D = (e_{max} - e)/(e_{max} - e_{min})$ |

### 3.4.2 Stresses in soils

| | | | |
|---|---|---|---|
| $\sigma$ | $ML^{-1}t^{-2}$ | (kN/m$^2$, kPa) | normal stress |
| $\sigma'$ | $ML^{-1}t^{-2}$ | (kN/m$^2$, kPa) | normal effective stress. $\sigma' = \sigma - u$ |
| $\sigma'_v$ | $ML^{-1}t^{-2}$ | (kN/m$^2$, kPa) | normal effective stress acting in a vertical direction |
| $\sigma'_h$ | $ML^{-1}t^{-2}$ | (kN/m$^2$, kPa) | normal effective stress acting in a horizontal direction |
| $U$ | $ML^{-1}t^{-2}$ | (kN/m$^2$, kPa) | pore water pressure |
| $\tau$ | $ML^{-1}t^{-2}$ | (kN/m$^2$, kPa) | shear stress |
| $\varepsilon$ | - | (%) | Strain |

### 3.4.3 Hydraulic properties

| | | | |
|---|---|---|---|
| $k$ | $Lt^{-1}$ | (m/s) | Coefficient of permeability (or hydraulic conductivity) |
| $I$ | - | (-) | hydraulic gradient |

### 3.4.4 Mechanical properties

#### 3.4.4.1 Soil behaviour under compressive strains

| | | | |
|---|---|---|---|
| $C_c$ | - | (-) | compression index (slope of virgin compression curve in a semi-logarithmic plot) |
| $C_r$ | - | (-) | recompression index (slope of recompression curve in a semi-logarithmic plot). |
| $C_\alpha$ | - | (-) | secondary compression index (slope of secondary compression curve in a semi-logarithmic plot). |
| $c_h$ | $L^2t^{-1}$ | (m$^2$/s) | vertical coefficient of consolidation (due to pore water movement in horizontal direction) |
| $c_v$ | $L^2t^{-1}$ | (m$^2$/s) | vertical coefficient of consolidation (due to pore water movement in vertical direction) |
| $m_v$ | $M^{-1}Lt^2$ | (m$^2$/MN) | coefficient of volume change (in vertical direction) |
| $\sigma'_p$ | $ML^{-1}\ t^{-2}$ | (kN/m$^2$, kPa) | pre-consolidation pressure (the greatest effective overburden pressure the soil mass has carried in the past) |
| $E$ | $ML^{-1}t^{-2}$ | (MN/m$^2$, MPa) | deformation modulus (ratio between a given normal stress change and the strain change in the same direction, all other stresses being constant) |
| $K'$ | $ML^{-1}t^{-2}$ | (MN/m$^2$, MPa) | Elastic bulk modulus. $K' = E/(3 - 6\nu)$ |
| $k_s$ | $ML^{-2}t^{-2}$ | (kN/m$^3$) | modulus of subgrade reaction (ratio between change of vertical stress on a rigid plate placed on the soil, and the corresponding change of vertical settlement of the plate) |
| $T_v$ | - | (-) | time factor, $T_v = t\ c_v/d^2$, where $t$ is time and $d$ is the length of the drainage path |
| $\nu$ | - | (-) | poisson's ratio (ratio between strain changes perpendicular to and in the direction of a given uniaxial stress change) |

#### 3.4.4.2 Soil behaviour under shear strains

| | | | |
|---|---|---|---|
| $\tau$ | $ML^{-1}t^{-2}$ | (kN/m$^2$, kPa) | shear strength. $\tau = c + \tan\ \phi$ |
| $\tau_u$ | $ML^{-1}t^{-2}$ | (kN/m$^2$, kPa) | shear strength measured under undrained (total stress) |

| | | | |
|---|---|---|---|
| | | | conditions. $\tau_u = c_u + \tan \phi_u$ |
| $\tau_d$ | $ML^{-1}t^{-2}$ | (kN/m², kPa) | shear strength measured under drained conditions. $\tau_d = c_d + \tan \phi_d$ |
| $\tau'$ | $ML^{-1}t^{-2}$ | (kN/m², kPa) | shear strength measured under effective stress conditions. $\tau' = c' + \tan \phi'$ |
| $\tau'_{cv}$ | $ML^{-1}t^{-2}$ | (kN/m², kPa) | residual shear strength measured under effective stress conditions . $\tau'_{cv} = c'_{cv} + \tan \phi'_{cv}$ |
| $c$ | $ML^{-1}t^{-2}$ | (kN/m², kPa) | cohesion |
| $c_u$ | $ML^{-1}t^{-2}$ | (kN/m², kPa) | cohesion measured under undrained conditions |
| $c_d$ | $ML^{-1}t^{-2}$ | (kN/m², kPa) | cohesion measured under drained conditions |
| $c'$ | $ML^{-1}t^{-2}$ | (kN/m², kPa) | cohesion measured under effective stress conditions |
| $c'_r$ | $ML^{-1}t^{-2}$ | (kN/m², kPa) | residual cohesion measured under effective stress conditions |
| $G'$ | $ML^{-1}T^{-2}$ | (MN/m², MPa) | elastic shear modulus. $G' = E/(2+2\nu)$. |
| $\phi$ | - | (°) | soil friction angle |
| $\phi_u$ | - | (°) | soil friction angle measured under undrained conditions |
| $\phi_d$ | - | (°) | soil friction angle measured under drained conditions |
| $\phi'$ | - | (°) | soil friction angle measured under effective stress conditions |
| $\phi'_{cv}$ | - | (°) | Critical state soil friction angle measured under effective stress conditions (shearing at constant volume) |
| $\phi'_r$ | - | (°) | residual soil friction angle measured under effective stress conditions |
| $\psi$ | - | (°) | soil dilation angle |
| $\psi'$ | - | (°) | soil dilation angle under effective stress conditions |
| $\mu$ | - | (-) | coefficient of friction of soil. $\mu = \tan \phi'$. |

## 3.5 Properties related to geotechnical structures

### 3.5.1 Structure dimensions

| | | | |
|---|---|---|---|
| *b*, *B* | L | (m) | breadth of foundation, slope or embankment |
| *D* | L | (m) | depth of foundation, depth below toe of slope |
| *h*, *H* | L | (m) | vertical height of wall, slope or embankment |
| *l*, *L* | L | (m) | length of foundation or embankment |
| *s* | L | (m) | settlement |
| *U* | - | (%) | degree of consolidation |
| $\beta$ | - | (°) | angle of slope to horizontal |

### 3.5.2 External applied loads

| | | | |
|---|---|---|---|
| $F_h$ | $MLt^{-2}$ or $Mt^{-2}$ | (kN or kN/m) | external applied concentrated horizontal force |
| $F_v$ | $MLt^{-2}$ or $Mt^{-2}$ | (kN or kN/m) | external applied concentrated vertical force |
| $w_s$ | $ML^{-1}t^{-2}$ | (kN/m², kPa) | external applied surcharge load |

### 3.5.3 Earth pressures

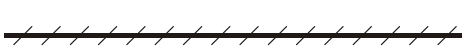
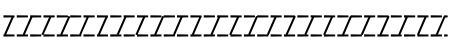
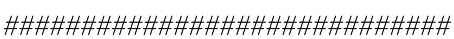
| | | | |
|---|---|---|---|
| $K$ | - | (-) | ratio of horizontal to vertical stress |
| $K_a$ | - | (-) | active earth pressure coefficient |
| $K_o$ | - | (-) | at-rest earth pressure coefficient |
| $K_p$ | - | (-) | passive earth pressure coefficient |
| $\alpha$ | $ML^{-1}t^{-2}$ | ($kN/m^2$, kPa) | wall adhesion (adhesion between wall and adjacent soil) |
| $\delta$ | - | (°) | angle of wall friction (angle of friction between wall and adjacent soil) |

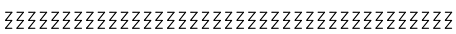
## 3.6 Factors of safety, partial factors and reduction factors

| | | | |
|---|---|---|---|
| $FS$ | - | (-) | global factor of safety (normally derived from limit equilibrium methods) |
| $f_{cr}$ | - | (-) | reduction factor associated with the loss in load carrying capability due to creep effects of a reinforcement over time |
| $f_f$ | - | (-) | partial factor associated with dead loads in a structure |
| $f_q$ | - | (-) | partial factor associated with live loads in a structure |
| $f_m$ | - | (-) | partial factor associated with the strength of the materials used in the structure |
| $f_{mr}$ | - | (-) | reduction factor associated with the loss in load carrying capability due to installation and durability effects of a reinforcement over time |
| $f_n$ | - | (-) | partial factor associated with the economic ramifications of structural failure |
| $f_p$ | - | (-) | partial factor associated with the pull-out resistance of geosynthetic reinforcements |
| $f_s$ | - | (-) | partial factor associated with the sliding resistance of geosynthetic reinforcements |

# 4. Graphical Symbols

## 4.1 Products

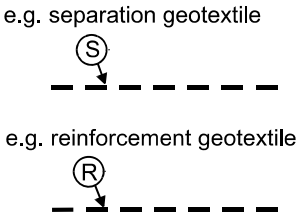
| | | |
|---|---|---|
| GTX |  | Geotextile (generic) |
| GMB |  | Geomembrane (generic) |
| GBA |  | Geobar (generic) |
| GBL |  | Geoblanket (generic) |
| GCD |  | Geocomposite drain (generic) – with geotextile on both sides |
| GCE |  | Geocell (generic) |
| GCL |  | Geocomposite clay liner (generic) |
| GEC |  | Surficial geosynthetic erosion control (generic) |

| | | |
|---|---|---|
| GEK |  | Electrokinetic geosynthetic (generic) |
| GGR |  | Geogrid (generic) |
| GMA |  | Geomat (generic) |
| GMT |  | Geomattress (generic) |
| GNT |  | Geonet (generic) |
| GSP |  | Geospacer (generic) |
| GST |  | Geostrip (generic) |

## 4.2 Functions

The following function symbols may be used where it is considered that a description of the role of the geosynthetic material may provide further clarity to the drawing or diagram.

| | |
|---|---|
| B | Barrier (fluid) |
| C | Containment (soil & sediments) |
| D | Drainage (fluid) |
| E | Surficial erosion control |
| F | Filtration |
| P | Protection |
| R | Reinforcement |
| S | Separation |




## 4.3 Multiple products on same diagram